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RESEARCH PRESSURE INSTRUMENTATION
FOR

NASA SPACE SHUTTLE MAIN ENGINE

NASA CONTRACT NO. NAS8-34769

MODIFICATION NO. 5

MONTHLY REPORT

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

August 1984

Prepared By:

P.J. ANDERSON, PROGRAM MANAGER
P. NUSSBAUM, TECHNICAL DIRECTOR
G. GUSTAFSON, DEPUTY TECHNICAL DIRECTOR

HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
12001 STATE HIGHWAY 55
PLYMOUTH, MN 55441



(NASA-CR-173932) RESEARCH PRESSURE
INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN
ENGINE Monthly Report (Honeywell, Inc.)
55 p HC A04/MF A01

CSCL 21H

N84-33463

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HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
CONTRACT NO. NAS8-34769
MODIFICATION NO. 5

RESEARCH OF PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE

Monthly R & D Progress Report August 1984 - Report No. 11

A. Technical Progress and Plans

- See attachment 'A'

B. Schedule

- See attachment 'B'

C. Status of Funds

D. Estimated percent of physical completion: 62%

E. At the present time the comparison of the cumulative costs to the percent of physical completion does not reveal any significant variance requiring explanation.

See Paragraph 4.0 for this discussion.

ATTACHMENT 'A'
RESEARCH PRESSURE INSTRUMENTATION
FOR
NASA SPACE SHUTTLE MAIN ENGINE
HONEYWELL, INC.

1.0 Introduction and Objective

The first phase of this contract (Tasks A and B) resulted in a highly successful demonstration in April 1983 at the MSFC of Honeywell's breadboard feasibility model of a silicon Piezoresistive Pressure Transducer suitable for SSME applications.

The purpose of Modification No. 5 of this contract is to expand the scope of work (Task C) of this research study effort to develop pressure instrumentation for the SSME. The objective of this contract (Task C) is to direct Honeywell's Solid State Electronics Division's (SSED) extensive experience and expertise in solid state sensor technology to develop prototype pressure transducers which are targeted to meet the SSME performance design goals and to fabricate, test and deliver a total of 10 prototype units.

SSED's basic approach is to effectively utilize the many advantages of silicon piezoresistive strain sensing technology to achieve the objectives of advanced state-of-the-art pressure sensors in terms of reliability, accuracy and ease of manufacture. More specifically, integration of multiple functions on a single chip is the key attribute of this technology which will be exploited during this research study.

The objectives of this research study will be accomplished by completing the following major tasks:

1. Transducer Package Concept and Materials Study

Three transducer design concepts will be generated and analyzed for the SSME application and materials/processes will be defined for the research prototype transducer design.

2. Silicon Resistor Characterization at Cryogenic Temperatures

The temperature and stress properties of a matrix of ion implanted piezoresistors will be characterized over the temperature range of -320°F to +250°F.

3. Experimental Chip Mounting Characterization

The mechanical integrity of chip mounting concepts will be evaluated over temperature, pressure and vibration.

4. Frequency Response Optimization

This task is a paper study which will specify and analyze an acoustic environment for which transducer frequency response can be determined and optimized.

5. Prototype Transducer Design, Fabrication, and Test

This major task will use the results generated in Tasks 1 through 4 above to design and develop a research prototype pressure transducer for the SSME application and will culminate in the delivery of 10 transducers, 5 each for the ranges of 0 to 600 psia and 0 to 3500 psia. This task is subdivided into the following five areas:

- Feasibility Evaluation of Transducer Concept
- Prototype Transducer Design
- Prototype Transducer Fabrication and Test
- Prototype Qualification
- Prototype Delivery.

6. Reports

Honeywell will submit monthly progress reports during the period of the contract; a final report will be provided at the completion of the contract.

The format of this report will be to discuss the work performed for this reporting period and the plans for the next reporting period for each of the major tasks outlined above.

2.0 Work Performed and Plans

2.1 Transducer Package Concept and Materials Study.

This task was completed per plan during January 1984.

2.2 Silicon Resistor Characterization at Cryogenic Temperatures.

This task was completed in May 1984.

2.3 Experimental Chip Mounting Characterization

2.3.1 Work performed in August

- Completed the assembly of two Sensor Mount assemblies using a Au/Ge solder. The glass-to-silicon nitride and silicon-to-silicon nitride solder joints were bonded simultaneously. The mechanical strength of the solder joints was very strong; however, the joints were not hermetic.
- Completed some failure analysis work on the aforementioned samples to determine the cause of the non-hermetic joints. It was established that there was incomplete melting and wetting of the Au/Ge solder to the Ti/Pt/Au base metallization. Five possible causes for this condition were identified, namely:
 - Base Metallization -- Gold in Ti/Pt/Au film too thin.
 - Loading of the parts during the soldering process--uneven.
 - Oven contamination.
 - Soldering Temperature Profile -- too slow a transition through the melting region.
 - Soldering temperature -- too low. This is thought to be the least likely cause because the solder joints were determined to be roughly 40°C over the solder melting point.
- Completed the following activities in support of identifying a process change(s) which will provide hermetic seals:
 - metalizing samples with gold ranging in thicknesses from 1600 Å to 5,000 Å.
 - Rebuilding of the soldering fixture to improve the uniformity of loading of the parts during the soldering operation.

2.3.2 Plans for September

The plans are as follows:

- Complete experiments designed to "debug" the assembly process, i.e., establish process changes which will yield hermetic solder joints.
- Pending the results of the aforementioned experiments, the following activities will be started:
 - The assembly of the Experimental Sensors (nonfunctional), i.e., Sensor Mount subassemblies installed in the Sensor Housing.
 - The fabrication of the dual function fixture for high pressure testing and high pressure leak checking.
 - Testing of the Experimental Sensors as the assembly of same is completed.

2.4 Frequency Response Optimization

This task was completed per plan in February 1984.

2.5 Temperature Sensor Network Concept Study.

This task was deleted when the contract was negotiated.

2.6 Prototype Transducer Design, Fabrication and Test

2.6.1 Feasibility Evaluation of Transducer Concepts.

2.6.1.1 Define/Finalize Concept for Feasibility Transducer.

This task was completed per plan as reported in May. The sensor chip design was presented in that report. Though not mentioned specifically, the sensor package will be the same as that developed for the Experimental Sensor. (Re: previous Monthly Reports.) Clearly, that design will be modified to reflect insights gained from the evaluation of the Experimental Sensor.

This task is closed.

2.6.1.2 Feasibility Demonstration of Sensing Concepts.

.1 Work performed in August

- Completed the design of all piece parts for the Feasibility Model except for the Invar tubes and the interconnect metallization pattern on the silicon nitride on Terminal Board No. 1. The Invar tubes will be used to provide a compliant electrical feedthrough in Terminal Board No. 2.
- Completed all the assemble tooling to support this fabrication activity except the mask required to delineate the metallization pattern on Terminal Board No. 1. Most of this tooling will be the same as that developed and used for the Experimental Sensor build.
- Completed wafer processing on five wafers and 100% electrical probe testing of same. Acceptable yields were obtained.

.2 Plans for September

The plans are as follows:

- Complete wafer saw and sort of the good chips.
- Complete TE bonding of the good sensor chips to the pyrex washer.
- Complete development tooling and procedures for delineating electrical interconnect pattern on Terminal Board No. 1. (Silicon nitride)
- Complete the fabrication of the compliant Invar feedthrough tubes.
- Start process/procedure development for hermetically soldering the Invar tubes to Terminal Board No. 2
- Regarding the decision to build a third stainless steel housing and base, we will not be building an additional housing and base. Because of budget constraints, we will use the pieces of hardware from the Experimental Transducer and modify them as required.
- NOTE: the fabrication of the Feasibility Sensor Mount assemblies will not be started until a process is developed for hermetic solder seals on the Experimental Sensor Mount assemblies.

2.7 Miscellaneous

2.7.1 Materials List

We received approval (Attachment 'C') of our materials list which was submitted for NASA approval on 24 May 1984. (Re: May Monthly Report, Attachment 'D')

2.7.2 Vibration Requirements

- Re: 1. NASA Contract No. NAS8 34769, 8/26/82
Exhibit 'A', Section B.1
2. Honeywell's Technical Proposal, 7/12/83,
Sections 2.3 (Pages 2-5 to 2-7),
2.6.1.2 (Pages 2-15 to 2-18),
2.6.1.4 (Page 2-36 and 2-37),

This topic was discussed at length during our 22 August 1984 Program Review at NASA/MSFC (Re: Paragraph 2.7.3) and during several subsequent telephone calls. The bottom line concern as expressed by Mr. H. Burke and Mr. W. White was that the original contract vibration requirements (Reference 1) to which Honeywell responded in its Technical Proposal (Reference 2) may be in error and/or Honeywell's interpretation of those requirements results in an unnecessarily severe set of requirements against which to test and evaluate the transducer's performance

This issue has not been resolved, but clearly resolution is required before any vibration testing is done. We understand Mr. White is working this problem and we look forward to resolution in the near-future. We recommend that we began using written communications via TelFax (Telecopy) to propose and evaluate alternative vibration requirements, their interpretation, and testing/evaluation methods. The ultimate goal being to achieve a clear definition of what is acceptable for the purposes of this contract.

2.7.3 Program Review

A Program Review was held at NASA/MSFC on 22 August 1984. Copies of our entire presentation were left with Mr. H. Burke and others present at the Review and is not included as part of this report. However, Attachment 'D' contains the Review Agenda, the Program Manager's overview of the program and his concluding remarks.

2.7.4 Risk Reduction Opportunities

This topic was discussed in some detail during our 22 August 1984 program review also. We subsequently submitted the entire presentation, under separate cover, to the NASA Contract Office. See Attachment 'E'. There is ample background and detailed discussion provided in Attachment 'E' such that further discussion is not required here.

2.7.5 Test Plans

At NASA's request, we have provided a detailed Test Plan for the Experimental Transducer. See Attachment 'F'. In addition, we provided an outline of the Test Plans for the Feasibility and Deliverable Transducers by referring to the appropriate sections of Honeywell's Technical Proposal. The later Test Plans will be detailed further as we approach the testing of those transducers.

3.0 Schedule

Some schedule slips have been incurred and are beginning to have an impact on planned activity at year-end. The Schedule section of Attachment 'D' provides an assessment of the impact of these slips as of 22 August 1984.

The difficulties being encountered in achieving hermetic solder seals may result in some additional schedule impact. A more complete assessment will be provided in our September report.

4.0 Cost Considerations

The elements that make up the "Estimate-at-completion" of \$463,450 are as follows:

• Additional Piece Part Costs	\$12.1K
• Reference Vacuum Process Development	<u>\$44.0K</u>
TOTAL	\$56.1K

The origin of these additional costs stem from two facts, namely,

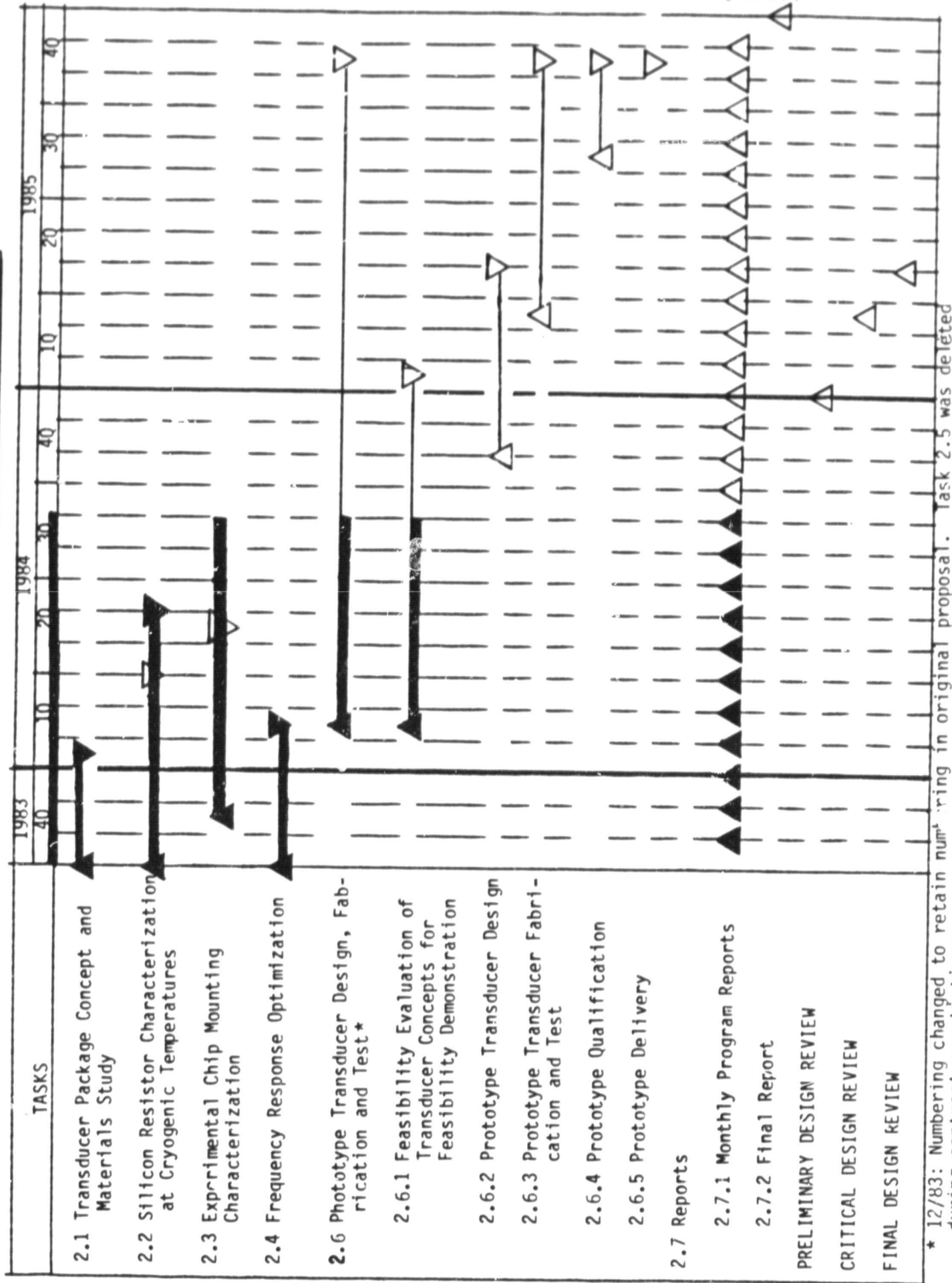
- The specific requirements of the Shuttle's electrical connector with which our transducer was required to interface was not available to us as we prepared our piece-part cost estimate for this item. Since that time, we have obtained those requirements and found that all that was available to us was a space qualified version and the price was substantially higher than we had estimated.

PAGE EIGHT

- At NASA's request, Honeywell's proposal was based on a "Best Shot" design approach for the transducer. Central to that approach was a design concept that assumed the reference vacuum could be established using previously developed processes and procedures at Honeywell/SSED. However, during the Concept Phase of this contract, it became clear that a significant deviation in our design concept was required to achieve a transducer that had performance targeted to meet NASA's requirements. The impact of this situation is a need for additional piece parts to support the hermeticity requirements and a unique process and procedure development activity to establish the reference vacuum for the present design. Additional discussion on these items is provided in Attachment 'G'. This material was also provided in the letter to the NASA Contract Office. See Attachment 'E'.

RESEARCH PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE SCHEDULE

ATTACHMENT B' ORIGINAL OF POOR QUALITY



* 12/83: Numbering changed to retain numbering in original proposal. Task 2.5 was deleted during contract negotiations.

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

ORIGINAL PAGE 10
OF POOR QUALITY

AUG 15 1984

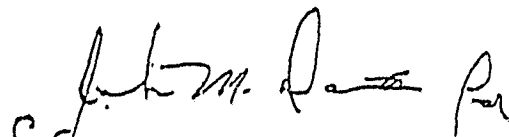
Reply to Attn of: EH02 (84-372)

TO: EB22/Mr. White

FROM: EH02/Mr. Key

SUBJECT: Evaluation of Materials List for SSME Hydrogen
Pressure Sensor by Honeywell

The subject materials list has been evaluated and is acceptable.



C. F. Key

Chief

Materials Selection & Control Office
Materials & Processes Laboratory

cc:

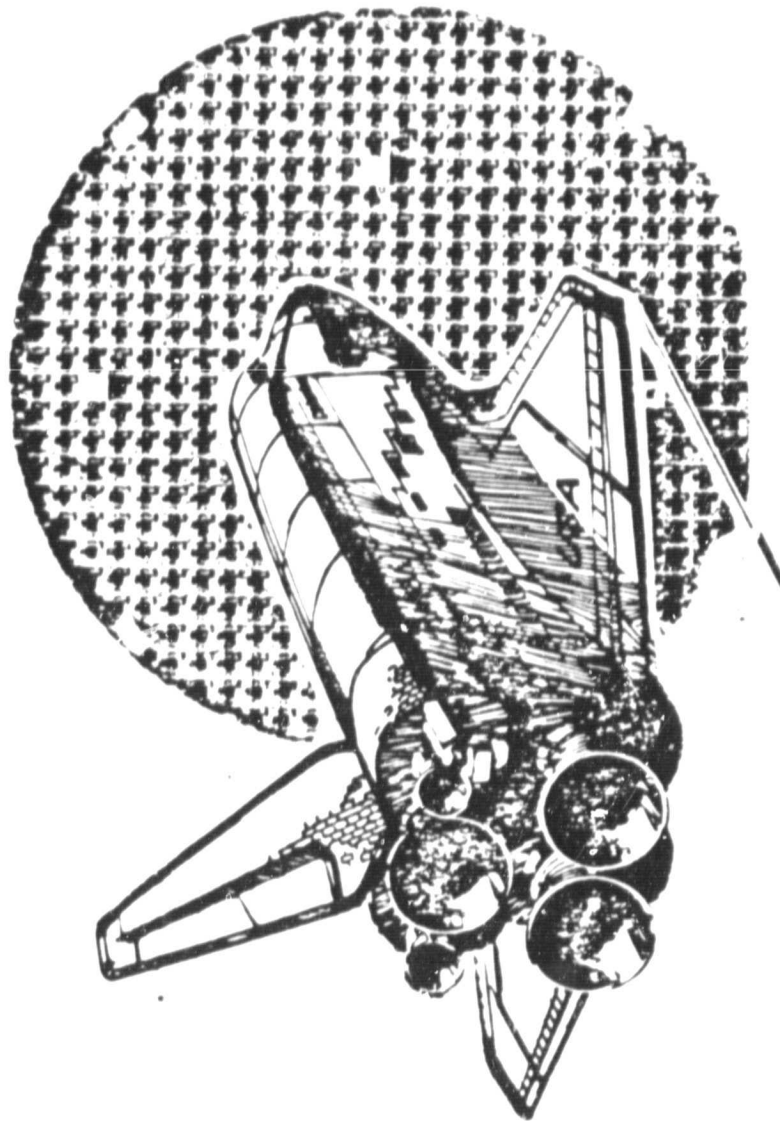
EH01/Mr. Schwinghamer

EH02/Mr. Knowling

NASA PRESSURE TRANSDUCER PROGRAM PROGRAM REVIEW

Honeywell

03/22/84



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ATTACHMENT "D"

Research of Pressure Instrumentation for Space Shuttle Main Engine

NASA PRESSURE TRANSDUCER PROGRAM RESEARCH STUDY OBJECTIVES

- OVERALL OBJECTIVE: ADVANCE STATE-OF-THE-ART
 DEFINE AND DEMONSTRATE NEW METHODS TO ADVANCE THE STATE-OF-THE-ART OF PRESSURE SENSORS IN TERMS OF RELIABILITY, ACCURACY AND EASE OF MANUFACTURE
- PHASE I OBJECTIVE: TECHNOLOGY DEMONSTRATION
 - DEVELOP BREADBOARD HARDWARE CAPABLE OF DEMONSTRATING THE FEASIBILITY OF AN ADVANCED TECHNOLOGY APPROACH TO PRESSURE SENSING
 - PROVIDE A LABORATORY DEMONSTRATION AT MSFC OF DELIVERED BREADBOARD HARDWARE EMBODYING THE ADVANCED PRESSURE SENSING TECHNOLOGY
- PHASE II OBJECTIVE: HARDWARE DEMONSTRATION
 - DESIGN AND DEVELOP AN ABSOLUTE PRESSURE TRANSDUCER FOR NASA/MSFC WITH PERFORMANCE TARGETED TO MEET NASA'S DESIGN GOALS FOR SPACE SHUTTLE MAIN ENGINE APPLICATIONS
 - DELIVER TEN (10) PROTOTYPE MODELS TO MSFC FOR SPACE SHUTTLE MAIN ENGINE TEST FIRINGS

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NASA PRESSURE TRANSDUCER PROGRAM
OBJECTIVE/DELIVERABLES

● OBJECTIVE:

TO DESIGN, BUILD, TEST, CALIBRATE AND DELIVER 10 ABSOLUTE
PRESSURE TRANSDUCERS TO NASA/MSFC WITH PERFORMANCE
TARGETED TO MEET NASA'S DESIGN GOALS FOR SPACE SHUTTLE MAIN
ENGINE APPLICATIONS

● DELIVERABLES:

- FIVE (5) TRANSDUCERS: 0-600 PSIA
- FIVE (5) TRANSDUCERS: 0-3500 PSIA
- MONTHLY REPORTS
- FINAL REPORT

NASA PRESSURE TRANSDUCER PROGRAM
MAJOR THRUSTS AND GOALS

- INCREASE THE RELIABILITY OF THE SSME PRESSURE TRANSDUCERS OVER THE EXISTING OPERATING TEMPERATURE RANGE OF -65°F TO $+165^{\circ}\text{F}$
- INCREASE THE TRANSDUCER OPERATING TEMPERATURE RANGE TO -423°F TO 250°F

NASA PRESSURE TRANSDUCER PROGRAM
HONEYWELL'S CONCEPT

- SINGLE CHIP
- ELECTRICAL CONVERSION OF SENSOR BEHAVIOR INTEGRATED ON SAME CHIP AS SOLID STATE PIEZORESISTIVE ELEMENTS
- PRESSURE RANGE ESTABLISHED BY CHANGING DIAPHRAGM THICKNESS
- EACH TRANSDUCER UNIQUELY CALIBRATED BY LASER TRIMMING OF ON-CHIP THIN FILM RESISTORS
- TEMPERATURE COMPENSATION ACHIEVED BY INTERACTION OF ON-CHIP ION IMPLANTED AND THIN FILM RESISTORS

NASA PRESSURE TRANSDUCER PROGRAM
APPROACH

- INTEGRATED, INTEGRATE, ...!
- APPLY HONEYWELL'S PRESSURE SENSOR DESIGN/MANUFACTURING EXPERIENCE BASE AND EXTEND IT, PARTICULARLY TO CRYOGENIC TEMPERATURES (LN₂: -320°F)* WITH HIGH PRESSURES (9500 PSIA) AND SEVERE VIBRATION CONDITIONS, TO ACHIEVE PERFORMANCE TARGETED AT MEETING NASA'S DESIGN GOALS
- COMPLETE CONCEPT/FEASIBILITY STUDIES TO PROVIDE A SOUND DESIGN DATA BASE FOR THE DESIGN AND FABRICATION OF THE PROTOTYPE PRESSURE TRANSDUCER
- DESIGN, BUILD, TEST, CALIBRATE THE PRESSURE TRANSDUCERS AND PERFORM LIMITED QUALIFICATION OVER PRESSURE, TEMPERATURE, AND VIBRATION

* ULTIMATE GOAL: LH₂ OR -423°F

N A S A P R E S S U R E T R A N S D U C E R P R O G R A M
T R A N S D U C E R A T T R I B U T E S

- SOLID STATE RELIABILITY AND ACCURACY
- HIGH VIBRATION AND PRESSURE CAPABILITY
- INTEGRATION OF SENSOR AND ELECTRONICS ON SINGLE CHIP
 - REDUCES PACKAGE COMPLEXITY
 - ELIMINATES ERRORS DUE TO THERMAL GRADIENTS
- EXTENDED TEMPERATURE RANGE CAPABILITY
 - INCREASED TO -423°F TO +250°F
 - ELIMINATES NEED TO REMOTE MOUNT TRANSDUCER
- PRECISION LASER TRIM CALIBRATION
- INCREASED ENGINE PERFORMANCE MONITORING CAPABILITY WITH ENHANCED FREQUENCY RESPONSE
- COMMON DESIGN FOR ALL PRESSURE RANGES
 - ENHANCES EASE OF MANUFACTURE
 - COST EFFECTIVE

NASA PRESSURE TRANSDUCER PROGRAM
TECHNOLOGY DEMONSTRATION
MAJOR TASKS

- CONCEPT DEVELOPMENT AND TRADE OFF STUDIES
- BREADBOARD HARDWARE DEVELOPMENT
- BREADBOARD HARDWARE FABRICATION
- BREADBOARD HARDWARE DEMONSTRATION

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NASA PRESSURE TRANSDUCER PROGRAM
HARDWARE DEMONSTRATION
MAJOR TASKS

- TRANSDUCER PACKAGE CONCEPT AND MATERIALS STUDY (2.1)
- SILICON RESISTOR CHARACTERIZATION AT CRYOGENIC TEMPERATURES (2.2)
- EXPERIMENTAL TRANSDUCER ① DESIGN, FABRICATION AND TEST (2.3)
- FREQUENCY RESPONSE OPTIMIZATION STUDY (2.4)
- FEASIBILITY TRANSDUCER DESIGN, FABRICATION AND TEST (2.6.1)
- DELIVERABLE (PROTOTYPE) TRANSDUCER DESIGN, FABRICATION AND TEST (2.6.2 - 2.6.4)
- DELIVER TEN TRANSDUCERS (2.6.5)

① Non-FUNCTIONAL

NASA PRESSURE TRANSDUCER PROGRAM
AGENDA: 8/22/84

- OPENING REMARKS P. J. ANDERSON
- PROGRAM REVIEW P. J. ANDERSON
 - OVERVIEW OF PROGRAM P. NUSSBAUM
 - TECHNICAL STATUS P. NUSSBAUM
- RECOMMENDED RISK REDUCTION OPPORTUNITIES H. BURKE
- BRIEFING ON NASA/MSFC "TEST BED ENGINE" PROGRAM ALL
- DISCUSSION P. J. ANDERSON
- CONCLUDING REMARKS

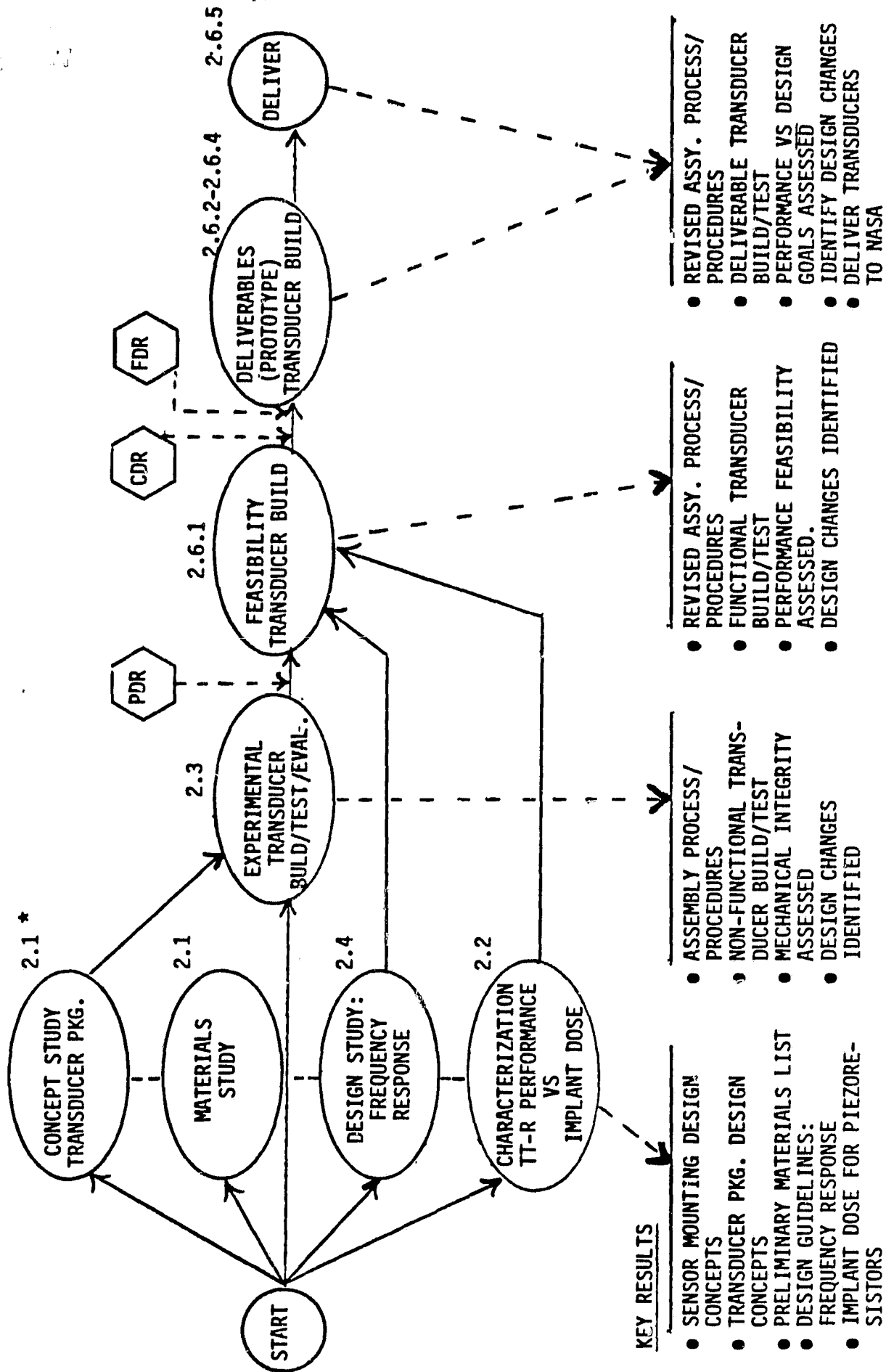
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N A S A P R E S S U R E T R A N S D U C E R P R O G R A M
P R O G R A M O V E R V I E W
O U T L I N E

- HONEYWELL, INC.
- OBJECTIVE/DELIVERABLES
- MAJOR THRUSTS/GOALS
- HONEYWELL'S CONCEPT
- APPROACH
- TRANSDUCER ATTRIBUTES
- MAJOR TASKS/EXPECTED RESULTS
- PROGRAM ORGANIZATION
- COST
- SCHEDULE

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NASA PRESSURE TRANSDUCER PROGRAM OVERVIEW MAJOR TASK STRUCTURE



* Proposal Task Notation

ORIGINATING OFFICE
OF POOR QUALITY

NASA PRESSURE TRANSDUCER PROGRAM
COSTS (THROUGH 8/3/84)

- TOTAL BASELINE PLAN: * \$ 407,350
- TOTAL FUNDED: * 300,000
- ACTUALS (8/3/84): 253,723
- INCEPT-TO-DATE PLAN: 206,440
- ESTIMATE AT COMPLETION: ~~463,450~~ ** 463,450

* RE: NASA CONTRACT No. NAS8-34769, MODIFICATION 5, 9/29/83

** INCLUDES:

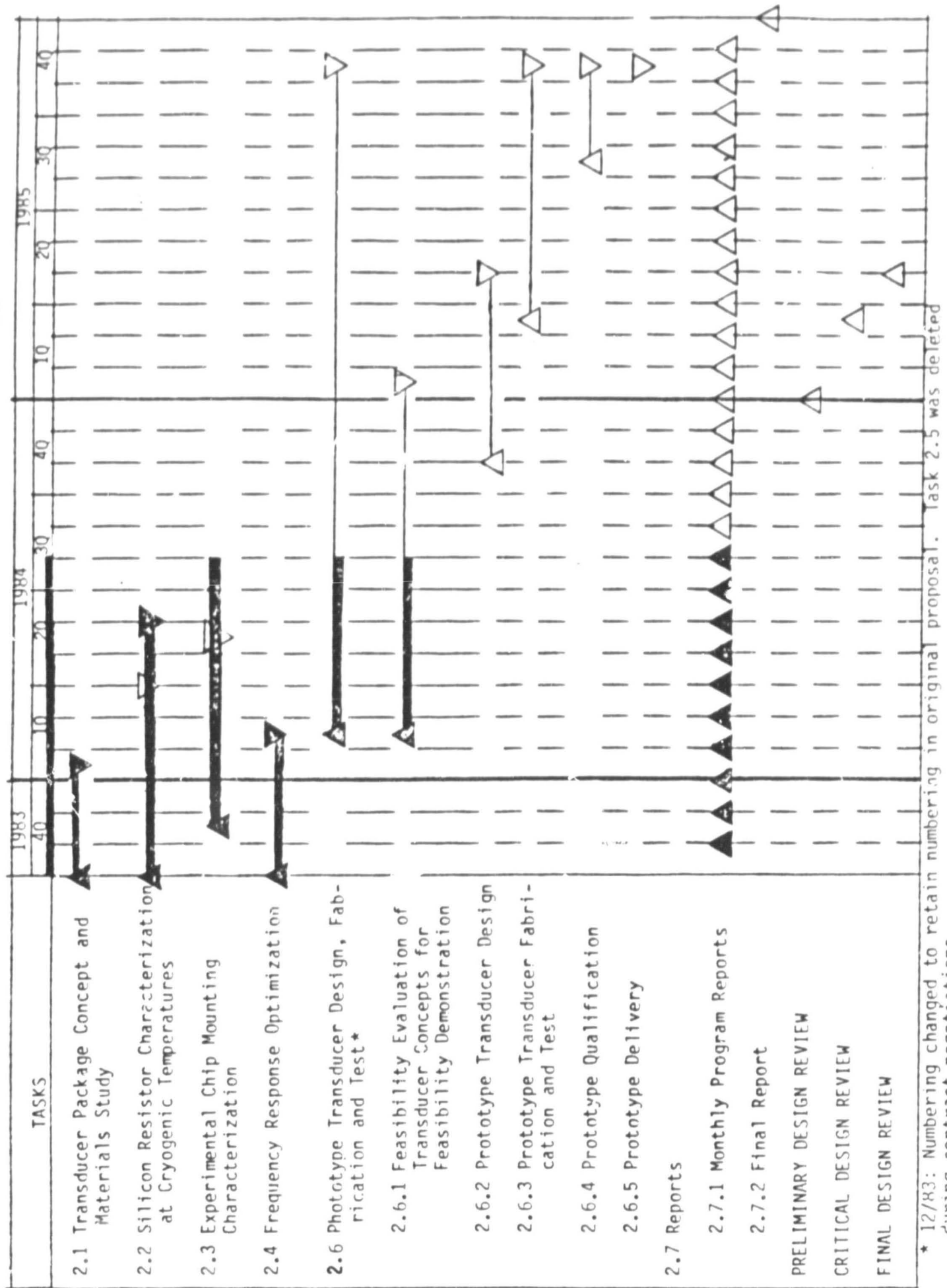
- ADDITIONAL UNEXPECTED PIECE-PART COSTS: ~ \$12K
- REFERENCE VACUUM PROCESS DEVELOPMENT: ~ \$ 44K

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8/22/84

RESEARCH PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE SCHEDULE

ATTACHMENT "D" (CONT'D)

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* 12/R3: Numbering changed to retain numbering in original proposal. Task 2.5 was deleted during contract modification.

NASA PRESSURE TRANSDUCER PROGRAM SCHEDULE

● STATUS

- SCHEDULE SLIPS HAVE BEEN INCURRED IN TASK 2.3 AND 2.6.1 (EXPERIMENTAL TRANSDUCER DESIGN/BUILD/TESTING)
- Δ -TO-PLAN: ~ 9 WEEKS
- REASON
 - o FIVE (5) WEEKS DELAY: DELIVERY OF SILICON NITRIDE PARTS
 - o FOUR (4) WEEKS SLIP: PROCESS DEVELOPMENT/WAFER PROCESSING/TRANSDUCER ASSEMBLY

● PROGRAM IMPACT

- TWO (2) - FOUR (4) WEEKS AT YEAR-END
- TASK IMPACTED
 - o FEASIBILITY TRANSDUCER BUILD/TESTING (2.6.1)
 - o PRELIMINARY DESIGN REVIEW (MAYBE)
 - o DELIVERABLE (PROTOTYPE) DESIGN (2.6.2) (NONE EXPECTED)

● ACTION TAKEN

- REPLANNED TASKS 2.3 AND 2.6.1
- REPLAN STRATEGY: PARALLELED 2.3 AND 2.6.1 MORE TO MINIMIZE IMPACT
- ASSUME SENSOR MOUNT PIECE-PART HARDWARE IS SAME AS FOR EXPERIMENTAL TRANSDUCER
- ACCELERATED ORDERING OF FEASIBILITY PIECE PARTS

NASA PRESSURE TRANSDUCER PROGRAM
TECHNICAL STATUS: 9/22/84
OUTLINE

- PHASE I: TECHNOLOGY DEMONSTRATION
- PHASE II: HARDWARE DEMONSTRATION
 - TRANSDUCER PACKAGE CONCEPT/MATERIALS STUDY
 - PIEZORESISTOR CHARACTERIZATION AT CRYOGENIC TEMPERATURES
 - EXPERIMENTAL TRANSDUCER DESIGN/FABRICATION/TESTING
 - FREQUENCY RESPONSE DESIGN STUDY
 - FEASIBILITY TRANSDUCER DESIGN/FABRICATION/TESTING

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8/22/84

NASA PRESSURE TRANSDUCER PROGRAM
CONCLUDING REMARKS

- TECHNICAL PROGRESS IS GOOD --- NO SURPRISES YET!
- THERE ARE SOME NON-TRIVIAL RISKS AHEAD OF US
 - SEVERAL RISK REDUCING OPPORTUNITIES HAVE BEEN IDENTIFIED AND DISCUSSED IN SOME DETAIL TODAY
 - WE RECOMMEND NASA FUND THESE TASKS TO INCREASE THE PROBABILITY OF SUCCESS OF ACHIEVING THE STATED PROGRAM OBJECTIVE
- COST
 - CURRENTLY OVER PLAN
 - PROJECTED STATUS AT YEAR END: ON PLAN
- SCHEDULE
 - CURRENTLY BEHIND
 - PROJECTED STATUS AT YEAR END: TWO (2) - FOUR (4) WEEKS SLIP
- HONEYWELL HAS A BETTER UNDERSTANDING OF "TEST BED ENGINE" PROGRAM

PJA
8/22/84

NASA PRESSURE TRANSDUCER PROGRAM
CONCLUDING REMARKS
(CONTINUED)

- THE INTRINSIC ATTRIBUTES AND INNOVATIVENESS OF HONEYWELL'S SILICON PRESSURE SENSING TECHNOLOGY WILL SIGNIFICANTLY ADVANCE THE STATE-OF-THE-ART OF PRESSURE TRANSDUCERS FOR THE SSME APPLICATION
- THE SUCCESSFUL COMPLETION OF THIS RESEARCH STUDY FOR NASA/MSFC WILL PROVIDE THE TECHNOLOGY BASE FOR THE DEVELOPMENT OF SPACE QUALIFIED ADVANCED PRESSURE TRANSDUCER HARDWARE FOR THE CURRENTLY OPERATIONAL SPACE SHUTTLE, AS WELL AS FOR FUTURE "SMART SENSORS" FOR THE NEXT GENERATION OF SPACE VEHICLES

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8/22/84

Honeywell

August 30, 1984

Procurement Office
George C. Marshall Space Flight Center
National Aeronautics and Space Admin.
Marshall Space Flight Center, AL. 35812

Attn: Mr. Edward M. Harper
Contracting Officer

Subject: NASA Contract NAS8-34769

Reference: Program Review at NASA/MSFC on 22 August 1984

Gentlemen:

Honeywell Inc. Solid State Electronics Division (SSED) provided a program review at MSFC on 22 August 1984 for the NASA/MSFC Sensor Group. As a part of that review, Honeywell SSED presented a request for additional funding on the subject contract to cover two "new scope items", and a strong recommendation that NASA/MSFC fund a group of "Risk Reduction Opportunities." These items would maximize Honeywell's ability to meet schedule and deliver pressure transducers with performance targeted to meet NASA design goals. The Sensor Group was provided with a copy of our entire presentation including the parts associated with the topics noted above. The following paragraphs offer a summary of these items.

"New Scope" Items

The general description of these items and their estimated rough order of magnitude costs are as follows:

	<u>R.O.M. Estimate</u>	<u>Funding Need Date</u>
• Additional Piece Part Costs	\$12,100	15 Mar 1985
• Reference Vacuum Process Development	\$44,000	3 Dec 1984
Total	\$56,100	

Honeywell views these items as "must do" and not within the scope of the current contract. They are therefore projected as a delta to the current NASA contract funding of \$407,350 making the estimated NASA cost at completion \$463,450. Attachments 'A' and 'B' to this letter provide additional background discussion on these items.

"Risk Reduction Opportunities"

The current contract has some significant risks associated with it, since it is a "best shot" or "single path" approach to the delivery of the contract end items on schedule. This "single path" approach was requested by NASA/MSFC as Honeywell was asked to downscope its original proposal. Currently Honeywell is eleven months into the contract with good progress to date and is cautiously optimistic about future progress. However, we believe in the best interest of the program, that these risk reduction items will avoid

- 2 -
ATTACHMENT "E" (CONT'D)

potential technical problems that would adversely impact cost, schedule and the performance of the end item deliverables. We are therefore strongly recommending that NASA/MSFC fund an approximately \$110,000 risk reduction program. A prioritized summary of our recommended risk reducing tasks is provided below:

<u>Priority</u>	<u>Risk Reduction Opportunity</u>	<u>ROM Cost Estimate</u>	<u>Recommended Start Date</u>
1	Sensor mounting: Load Bearing Seal Options-Phase I (Design/Procurement)	\$8,000	1 Oct 1984
2	Lead-Length Reduction-Phase I (Demonstration of two approaches to reduce lead length)	\$29,000	4 Sept 1984
3	Error Source Analysis (Package vs Chip level influences)	\$33,000	4 Sept 1984
4	Hemeticity: Electrical Feed-throughs-Phase I (Concept Development: design, materials, assembly processes)	\$8,000	10 Dec 1984
5	Additional Cryogenic Data (Piezoreistors, CrSi thin film resistors, junction diodes)	\$15,000	1 Oct 1984
6	Sensor Chip Metallization	\$17,000	4 Sept 1984
Total		\$110,000	

Attachment 'C' to this letter provides additional discussion on items of an overview/benefits nature. Attachment 'D' summarizes the areas of concern and presents a more detailed discussion on each of the identified risk reduction opportunities. Also enclosed as Attachment 'E' are the summary charts used during the reference meeting. Note that items prioritized as 1, 2 and 4 above are split into two phases. The phase I activity is preparatory in nature providing alternate courses of action ready for implementation. The phase II activity is that required to implement the alternate or back-up approach. The first chart in Attachment 'E' provides a summary of costs for implementing these tasks.

In summary, Honeywell Inc. SSED is requesting NASA/MSFC to provide increased funding on the subject contract of an estimated \$56,100 for the "new scope" items; additional piece part costs and process development. In addition, Honeywell strongly recommends that NASA/MSFC fund an estimated \$110,000 of risk reduction tasks.

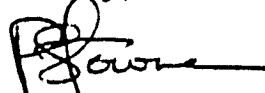
ATTACHMENT "E" (CONT'D)

These items will increase the probability of an on schedule delivery with performance targeted to meet NASA/MSFC SSME requirements. In the event that all risk reduction tasks and phase II tasks need to be implemented, the contract cost would be an estimated \$626,450..

Your comments on the tasks outlined above are requested at your earliest convenience to assist in Honeywell's program planning.

If you have any questions please contact Mr. Paul Anderson, Program Manager on 612/541-2085 or the undersigned on 612/541-2985.

Sincerely,



Paul L. Towne
Senior Contract Administrator

PLT:mka
attachments

cc: H. Burke MSFC
T. Marshall MSFC
J. Goldstein MSFC

ORIGINAL PAGE 19
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RESEARCH OF PRESSURE INSTRUMENTATION
ADDITIONAL PIECE PART COSTS

● OBJECTIVE

Honeywell requests \$12.1k additional funding for the Research of Pressure Instrumentation Program to cover the cost of package piece parts estimated or not anticipated when the program cost was negotiated with MSFC.

● BACKGROUND

- Exact cost information on NASA-specified electrical connectors was unavailable for Honeywell's proposal. These were estimated by Honeywell.

-The concept originally proposed assumed a single gold-germanium solder preform would be required to assemble the package. The current concept requires 12 preforms.

-Metal seal rings were not part of the original concept and were not included in the original piece part estimate.

● COST DETAIL

ITEM	PROPOSAL COST ESTIMATE	ACTUAL COST
Connectors	35 @ \$71 = \$2500	35 @ \$300 = \$10,500
Preforms	\$1250	\$ 3,322
Metal seal rings	<u>\$ 0</u>	20 @ \$101 = <u>\$ 2,020</u>
TOTALS	\$3750	\$15,842
		DELTA = \$12092

RESEARCH OF PRESSURE INSTRUMENTATION
NEW SCOPE TASK
REFERENCE VACUUM PROCESS DEVELOPMENT

● RATIONALE FOR NEW SCOPE

- Current package concept is significantly different from originally proposed design with respect to incorporating a stable absolute reference.
 - Because reference vacuum assembly process existed for original concept, program scope did not include a task for reference vacuum assembly process development.
- PROGRAM IMPACT WITHOUT REQUESTED SCOPE CHANGE
- Feasibility for producing absolute pressure sensors with the proposed package concept may not be demonstrated.
 - Deliverables may be gauge devices.

● APPROACH:

Develop assembly processes to achieve a reference vacuum with the current design

- Cost: \$44k Schedule: 18 weeks
- Recommended start date no later than 12/3/84

● EXPECTED RESULTS:

An assembly process for obtaining a 0.2psi reference vacuum with the current package design

RESEARCH OF PRESSURE INSTRUMENTATION RISK REDUCTION OPPORTUNITIES OVERVIEW

- THE RESEARCH OF PRESSURE INSTRUMENTATION STUDY HAS BEEN A HIGH-RISK PROGRAM FROM INCEPTION
 - Challenges in applying Honeywell's pressure sensor technology to the SSME application dictated a high-cost low-risk program be proposed in response to the RFQ.
 - Strategy of a high-risk single concept approach was requested by MSFC to limit initial program costs.
- HONEYWELL HAS IDENTIFIED SPECIFIC KEY AREAS IN WHICH THE PROGRAM RISK CAN BE SUBSTANTIALLY REDUCED
 - The key areas have been identified as a result of progress to date in the program.
 - Because specific areas for risk reduction have now been defined, it is possible to substantially reduce risk with a relatively small delta in total program cost.
- HONEYWELL STRONGLY RECOMMENDS THAT THE RISK REDUCTION OPPORTUNITIES BE PURSUED. WE HAVE:
 - A high confidence that the advantages of utilizing our solid state sensor technology for the SSME are substantial
 - A strong desire to make this program a success!

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION OPPORTUNITIES
PROGRAM BENEFITS FROM THE RISK REDUCTION TASKS

- PARALLEL RISK REDUCTION TASKS PUT ALTERNATIVE APPROACHES FOR KEY DESIGN AND ASSEMBLY STEPS IN PLACE IN ANTICIPATION OF A NEED, MAXIMIZING HONEYWELL'S ABILITY TO MEET SCHEDULE ON THE DELIVERABLES
 - RECOMMENDING THIS APPROACH ONLY FOR 4 CRITICAL AREAS
 - A MAJOR BENEFIT IS ELIMINATION OF LONG LEAD TIMES FOR CUSTOM PIECE PARTS (SAVE 2-5 MONTHS BY ORDERING IN ADVANCE OF NEED)
 - BASIC CONCEPTS AND FEASIBILITY FOR ASSEMBLY PROCESSES WILL BE DEVELOPED, BUT NOT IMPLEMENTED ON HARDWARE UNTIL NEED ARRISES
- RISK REDUCTION TASKS WILL SIGNIFICANTLY IMPROVE HONEYWELL'S ABILITY TO DELIVER TRANSDUCERS WHICH MEET THE SSME ACCURACY TARGETS OVER THE FULL PRESSURE, TEMPERATURE AND VIBRATION RANGES
 - DATA BASE FOR THE COMPENSATION CIRCUIT DESIGN WILL BE ENHANCED, INCREASING OUR CONFIDENCE OF MINIMIZING RESIDUAL ERROR
 - SPECIAL TEST SENSORS WILL HELP ISOLATE SOURCES OF RESIDUAL ERROR

RESEARCH OF PRESSURE INSTRUMENTATION RISK REDUCTION OPPORTUNITIES AREAS OF CONCERN

- MAJOR AREAS OF CONCERN
 - DESIGN AND ASSEMBLY OF KEY COMPONENTS IN THE ABSOLUTE TRANSDUCER PACKAGE
 - PERFORMANCE AT CRYOGENIC TEMPERATURES
- DESIGN AND ASSEMBLY OF KEY COMPONENTS IN THE ABSOLUTE TRANSDUCER PACKAGE
 - Sensor Mount Load Bearing Seal Rings
 - Electrical Lead Length
 - Electrical Feedthrough Hermeticity
 - Sensor chip metallization
- PERFORMANCE AT CRYOGENIC TEMPERATURES
 - Characterization at cryogenic temperatures of key compensation circuit components
 - Isolation of package-Induced residual error from silicon chip-Induced residual error
 - Sensor chip metallization

RISK REDUCTION TASK
SENSOR MOUNT LOAD-BEARING SEAL RING OPTIONS

- **CONCERN:**
Current metal c-ring seal design may not maintain hermeticity over the full range of pressure, temperature, and vibration
- **BASIS OF CONCERN:**
Hermetic seal ring concept has not been demonstrated for this application
- **IMPACT:**
 - Possible catastrophic transducer failure if hermeticity not maintained.
 - Delta to completion of deliverables caused by lead time to procure and implement alternative seal rings is 22 weeks
- **APPROACH:**
 - Phase 1: Design and procure a variety of alternative metal seal c-rings and v-rings as soon as possible
 - Addresses lead time concern
 - Cost: \$8k Schedule: 14 weeks
 - Recommended start no later than 10/1/84
 - Phase 2: Test and evaluate the alternative seal rings with existing sensor hardware if the current design is unsatisfactory, as shown during feasibility testing
 - To be performed only if current design fails
 - Cost: \$15k Schedule: 8 weeks
 - Start date (if needed) 1/7/85

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
SENSOR MOUNT LOAD-BEARING SEAL RING OPTIONS, CONT.

- EXPECTED RESULTS:
 - Reduction of the schedule delta by two months should the current design fail
 - A revised seal ring design which provides improved performance over the pressure, temperature, and vibration range.

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
LEAD LENGTH REDUCTION

- **CONCERN:**
The sensor-to-terminal board leads may fall the SSME vibration requirement.
- **BASIS FOR CONCERN:**
 - Leads on current design are 20 mills longer than on original concept
 - Lack of experimental data on lead failure over the range of SSME vibration requirements
- **IMPACT:**
Catastrophic failure during vibration testing requiring a redesign of the sensor-to-terminal-board interconnection
 - Program cost delta: \$32k
 - Program schedule delta: 32 weeks
- **APPROACH:**
Develop and demonstrate one of two alternative approaches to reduce lead length:
 - A rigid metallized insert with conductors
 - Replacement of the pyrex washer used to attach the chip to silicon nitride with a glass frit joint
- Phase 1: Demonstrate feasibility of these alternate approaches
 - Cost: \$29k Schedule: 20 weeks
 - Recommended start no later than 9/4/84
- Phase 2: Implement better of two alternate approaches on deliverables
 - Cost: \$6k Schedule: 12 weeks
 - Recommended start no later than 1/21/85

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
LEAD LENGTH REDUCTION,CONT.

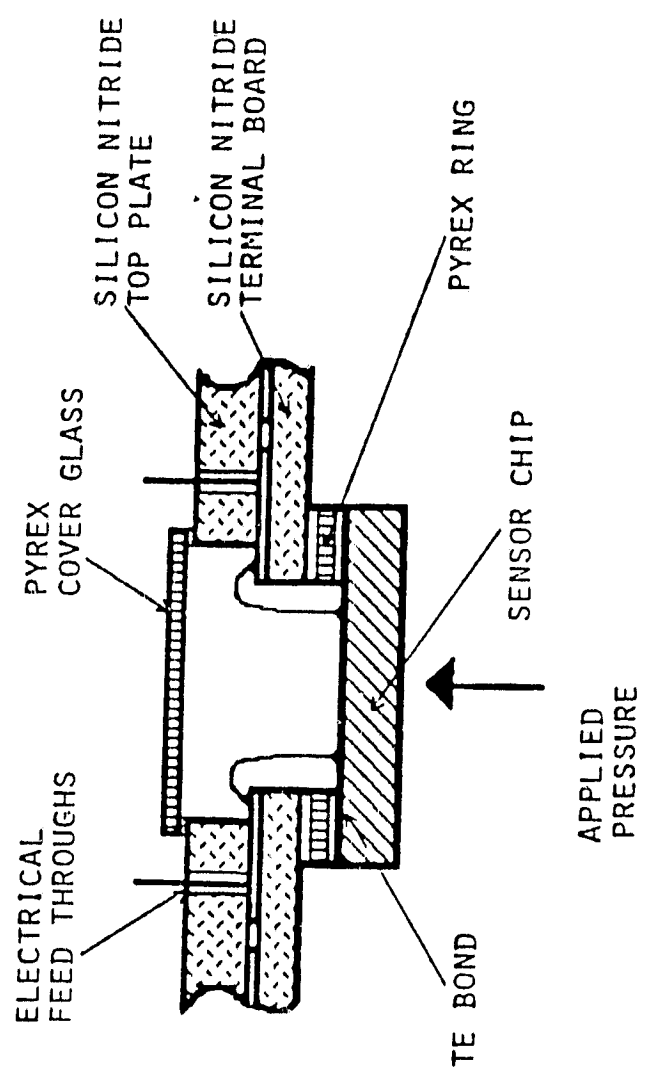
- EXPECTED RESULTS:
 - Reduction in lead length by at least 20 mils
 - Established feasibility of alternate interconnection approach
 - Materials and processes for implementing technique on deliverables

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
ERROR SOURCE ANALYSIS

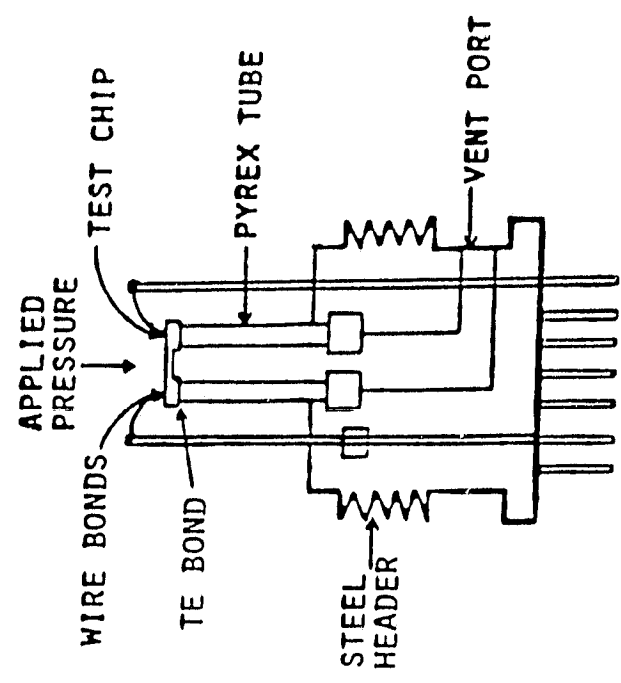
- **CONCERN:**
Current sensor/package design may result in residual uncompensatable error
- **BASIS OF CONCERN:**
SSME environmental requirements dictate significant deviation from our sensor and package design/experience data base. Uncompensated error sources may result.
- **IMPACT:**
Accuracies potentially achievable with this technology may not be well-demonstrated on the deliverables
- **APPROACH:**
Mount and evaluate feasibility sensor chips in a package for which performance influences are well characterized
 - Cost: \$33k Schedule: 10 weeks
 - Recommended start date no later than 9/4/84
- **EXPECTED RESULTS:**
An assessment of the differences in a selected set of performance parameters between the "standard" package and the current SSME design

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
ERROR SOURCE ANALYSIS

SSME DESIGN



STANDARD PACKAGE



ORIGINAL FIGURE
OF POOR QUALITY

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
HERMETICITY OF ELECTRICAL FEEDTHROUGHS

- **CONCERN:**
Current feedthrough design at sensor chip mount may not maintain reference pressure for an absolute device (ie., non-hermetic seal)
- **BASIS OF CONCERN:**
Proposed feedthrough design and assembly process have not been demonstrated
- **IMPACT:**
Failure to demonstrate concept feasibility for an absolute sensor.
- **APPROACH:**
 - Phase 1: Investigate alternative materials and processes for achieving hermetic electrical feedthroughs in sensor mount.
 - Cost: \$8k Schedule: 6 weeks
 - Recommended start date no later than 12/10/84
 - Phase 2: Demonstrate feasibility of an alternative method for fabricating hermetic electrical feedthroughs on existing hardware.
 - Cost: \$31k Schedule: 14 weeks
 - Recommended start date (if needed) 1/21/85
- **EXPECTED RESULTS:**
A back-up design and process to achieve hermetic chip-to-terminal board electrical feedthroughs.

**RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
ADDITIONAL CRYOGENIC DATA**

- **CONCERN:**
Data base for performance of sensing resistors and compensation circuit components at cryogenic temperatures is limited.
- **BASIS FOR CONCERN:**
Only limited basic cryogenic characterization of key components has been performed (3 runs to -320°F on 9 piezoresistive sensor elements)
- **IMPACT:**
Accuracies potentially achievable with this technology may not be well-demonstrated on the deliverables.
- **APPROACH:**
 - Perform testing and evaluation of these components at cryogenic temperatures:
 - Piezoresistive sensor elements (additional testing)
 - CrSi Thin Film Resistors (new testing)
 - Junction Diodes (new testing)
- Cost and Schedule: \$15k 5 weeks
 - Assumes Error Source Analysis Task Is conducted
 - Recommended start date no later than 10/1/84
- **EXPECTED RESULTS:**
Obtain a data base on the temperature characteristics of the circuit components sufficient to design an accurate compensation network for the deliverables.

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
SENSOR CHIP METALLIZATION

● CONCERN:

- Current program funding level does not allow any process options to be tested on the sensor chip.
- Modelling, experimental data, and assembly experience indicate noble metallurgy offers performance and yield advantages over aluminum metallurgy.
- Current feasibility sensor chip is metallized with aluminum.

● BASIS OF CONCERN:

- Noble-metallization process applicable to current design has just completed development.
- Well-established aluminum process was selected because it is lowest risk with respect to assured delivery of sensor chips. Noble metal would have been selected if assured of, on-schedule delivery available.

● IMPACT:

Aluminum-metallized chips may have degraded performance or catastrophic lead failure.

● APPROACH:

Fabricate noble-metallized sensors in parallel with aluminum-metallized sensors. Utilize noble-metallized sensors if fabrication successful, with aluminum-metallized sensors available as back-up.

- Cost: \$17k Schedule: 2-5 weeks
- Recommended start date no later than 9/4/84

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION TASK
SENSOR CHIP METALLIZATION, CONT.

- EXPECTED RESULTS:
Low risk approach to achieve sensor chips with improved performance and assembly yield.

RESEARCH OF PRESSURE INSTRUMENTATION
RISK REDUCTION OPPORTUNITIES
SUMMARY AND RECOMMENDATION

<u>● SUMMARY</u>			
<u>PRIORITY</u>	<u>TASK</u>	<u>RATIONALE FOR PRIORITY</u>	<u>FUNDING(k\$)</u>
1	Seal Ring Options	Possible catastrophic failure 14 wk lead time for alternate designs	Phase 1 8.0 Phase 2 15.0
2	Lead Length Reduction	Possible catastrophic vibration failure. 32 wk delivery Impact	Phase 1 29.0 Phase 2 7.0
3	Error Source Analysis	Larger than desired transducer inaccuracies	33.0
4	Feedthrough Hermeticity	Absolute sensor concept not demonstrated	Phase 1 8.0 Phase 2 31.0
5	Additional Cryo- genic Data	Larger than desired transducer inaccuracies	15.0
6	Sensor Chip Metal.	Larger than desired transducer inaccuracies	17.0
		TOTALS	110.0
● RECOMMENDATION:	FUND PHASE 1 ON PRIORITIES 1,2,3,4		53.0
	FUND PRIORITIES 3,4,5		FUNDING: \$110k

RESEARCH OF PRESSURE INSTRUMENTATION
ADDED SCOPE, ADDITIONAL PIECE PARTS, AND
RECOMMENDED RISK REDUCTION OPPORTUNITIES

FUNDING SUMMARY

● <u>COSTS ESTIMATED IN PROPOSAL WHICH ARE NOW DEFINED</u> ADDITIONAL PACKAGE PIECE PARTS	<u>\$K</u> 12.1
● <u>ADDED SCOPE FOR NEW PACKAGE CONCEPT</u> REFERENCE VACUUM PROCESS DEVELOPMENT	<u>44.0</u> 56.1
● <u>RECOMMENDED RISK REDUCTION TASKS</u> SENSOR MOUNT LOAD-BEARING SEAL OPTIONS (PHASE 1)	8.0
LEAD LENGTH REDUCTION	29.0*
ERROR SOURCE ANALYSIS	33.0
HERMETICITY OF ELECTRICAL FEEDTHROUGHS (PHASE 1)	8.0
ADDITIONAL CRYOGENIC DATA	15.0
SENSOR CHIP METALLIZATION	<u>17.0</u>
TOTAL	110.0
	<u><u>166.1</u></u>

*Need for this task will be determined by 9/7/84

ATTACHMENT "F"
Honeywell

ORIGINAL PAGE NO
OF POOR QUALITY

August 28, 1984

MR. HARLAN BURKE
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER, AL 35812

RE: 1. NASA CONTRACT NAS8-3469
2. PROGRAM REVIEW AT NASA/MSFC, 8/22/84

DEAR HARLAN:

DURING OUR 22 AUGUST 1984 REVIEW, YOU REQUESTED THAT WE OUTLINE OUR TESTING PLANS FOR THE EXPERIMENTAL, FEASIBILITY AND DELIVERABLE (PROTOTYPE) TRANSDUCERS FOR YOUR REVIEW AND COMMENT. I HAVE ENCLOSED AS ATTACHMENT "A" THE TEST PLAN FOR THE EXPERIMENTAL TRANSDUCER. I WILL FORWARD THE OTHER TEST PLANS TO YOU AT A LATER DATE AND UNDER A SEPARATE COVER. IN THE MEANTIME, YOU MAY WISH TO REVIEW THE TESTING SCOPE AS IT WAS DETAILED IN OUR JULY 1983 PROPOSAL FOR THESE TRANSDUCERS. THE APPLICABLE PAGE NUMBERS ARE AS FOLLOWS:

- o EXPERIMENTAL TRANSDUCER: pp: 2-5 TO 2-7
- o FEASIBILITY TRANSDUCER: pp: 2-15 TO 2-19
- o DELIVERABLE TRANSDUCER: pp: 2-32 TO 2-35
(PROTOTYPE) 2-36 TO 2-39

WE WELCOME YOUR COMMENTS ON THE ENCLOSED TEST PLAN AND ALSO YOUR PLANS FOR A MEMBER OF THE SENSOR GROUP TO WITNESS OUR TESTING ACTIVITIES. WE EXPECT THIS TESTING TO START IN ABOUT ONE-TO-TWO WEEKS.

SINCERELY,



P. J. ANDERSON
PROGRAM MANAGER
MS: MN14-3B20

ATTACHMENT (1)

cc: P. TOWNE, 4C25	J. ONFFROY, 3B35
P. J. ANDERSON, 3B20	G. GUSTAFSON, 3B35
D. WAMSTAD, 3B35	W. B. WHITE, NASA/MSFC
P. NUSSBAUM, 3B35	J. MARSHALL "
J. MOYLAN, 4C20	J. GOLDSTEIN "

ATTACHMENT "A"

NASA PRESSURE TRANSDUCER PROGRAM

RE: NASA CONTRACT: NASA-34769

EXPERIMENTAL PRESSURE TRANSDUCER
TEST PLAN

- I. OBJECTIVE: TO DETERMINE THE MECHANICAL INTEGRITY OF THE SENSOR MOUNTING ASSEMBLED WITHIN THE TRANSDUCER PACKAGE OVER TEMPERATURE, PRESSURE AND VIBRATION.
- II. TEST DEVICE: AN ELECTRICALLY NON-FUNCTIONAL VERSION OF HONEYWELL'S CURRENT DESIGN APPROACH.
- III. EVALUATION METHODS
 - A. PHYSICAL CONDITION -- VISUAL
 - B. HERMETICITY OF JOINTS AND SEALS -- HELIUM LEAK CHECK
 - C. CONTINUITY OF "DUMMY" ELECTRICAL LEADS -- VISUAL AND CONTINUITY CHECK
- IV. TEST PLAN
 - A. SAMPLE SIZES = 2 UNITS
 - B. BASELINE CONTINUITY CHECK
 - C. BASELINE LEAK CHECK
 1. AT ATMOSPHERIC PRESSURE
 2. AT 1500 PSI OF HELIUM PRESSURE
 - D. BASELINE PRESSURE TEST
 1. TEST GAS: NITROGEN
 2. APPLY 3500 PSI
 3. LEAK CHECK AT ATMOSPHERIC PRESSURE
 4. APPLY 6000 PSI
 5. LEAK CHECK AT ATMOSPHERIC PRESSURE
 6. APPLY 10,000 PSI
 7. LEAK CHECK AT ATMOSPHERIC PRESSURE
 - E. EVALUATION
 1. DISASSEMBLE FIRST UNIT
 2. CONTINUITY CHECK
 3. VISUALLY INSPECT AND NOTE RESULTS
 4. HELIUM BOMB FIRST UNIT
 5. LEAK CHECK AT ATMOSPHERIC PRESSURE
 - F. DECISION
 1. PENDING RESULTS FROM E. ABOVE, REPEAT STEPS B-E.
 - G. SAMPLE PREPARATION FOR NEXT TEST
 1. REASSEMBLE TEST DEVICES(S)
 2. LEAK CHECK AT 1500 PSI OF HELIUM

ATTACHEMENT "A" CONT'D.

- H. VIBRATION TESTING -- PART I
 - 1. SAMPLE SIZE: 2 UNITS
 - 2. SINUSOIDAL SWEEP ONLY
 - a. 150-200 Hz @ 130 g's PEAK
 - b. 200-300 Hz @ 150 g's PEAK
 - c. 170 Hz @ 120 g's PEAK
- I. EVALUATION
 - 1. LEAK CHECK AT 1500 PSI HELIUM
 - 2. DISASSEMBLE
 - 3. CONTINUITY CHECK
 - 4. VISUAL INSPECTION AND NOTE RESULTS
- J. SAMPLE PREPARATION FOR NEXT TEST
 - 1. REASSEMBLE
 - 2. LEAK CHECK (HERMETICITY NOT REQUIRED, JUST NOTE LEAK RATE)
- K. VIBRATION TESTING -- PART II
 - 1. SAMPLE SIZE = 2 UNITS
 - 2. SINUSOIDAL SWEEP ONLY
 - a. 2000 Hz @ 400 g's PEAK
- L. EVALUATION
 - 1. LEAK CHECK AT ATMOSPHERIC PRESSURE
 - 2. DISASSEMBLE
 - 3. CONTINUITY CHECK
 - 4. VISUAL INSPECTION AND NOTE RESULTS
- M. SAMPLE PREPARATION FOR NEXT TEST
 - 1. LEAK CHECK SENSOR MOUNT SUBASSEMBLY
 - 2. REASSEMBLE
 - 3. CONTINUITY CHECK
- N. TEMPERATURE SHOCK TESTING
 - 1. IMMERSE IN LIQUID NITROGEN
 - a. IMMERSE IN LN₂ FOR 10 MINUTES
 - b. IMMEDIATELY PLACE ON TO HOT PLATE AT 250°F FOR 20 MINUTES
 - c. REPEAT A AND B SEQUENCE TWO MORE TIMES IN SUCCESSION
- O. EVALUATION
 - 1. LEAK CHECK AT ATMOSPHERIC PRESSURE
 - 2. DISASSEMBLE
 - 3. VISUAL INSPECTION AND NOTE RESULTS
 - 4. LEAK CHECK SENSOR MOUNT SUBASSEMBLY
 - 5. CONTINUITY CHECK
- P. END OF TESTING/EVALUATION OF EXPERIMENTAL TRANSDUCER MODEL

RESEARCH OF PRESSURE INSTRUMENTATION ADDITIONAL PIECE PART COSTS

0 OBJECTIVE

Honeywell requests \$12.1k additional funding for the Research of Pressure Instrumentation Program to cover the cost of package piece parts estimated or not anticipated when the program cost was negotiated with MSFC.

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RESEARCH OF PRESSURE INSTRUMENTATION
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